(12) **UK Patent Application** (19) **GB** (11) **2 162 025 A**

(43) Application published 22 Jan 1986

(21) Application No 8516291

(22) Date of filing 27 Jun 1985

(30) Priority data

(31) 8416496   (32) 28 Jun 1984   (33) GB

(71) Applicant
Reginald Alfred King
6 Clevedon Road, Tilehurst, Reading, Berkshire

(72) Inventor:
Reginald Alfred King

(51) INT CL⁴
G10L 9/18

(52) Domestic classification
H4R PVA

(56) Documents cited
None

(58) Field of search
H4R

(74) Agent and/or Address for Service
G. Sorenti, The Plessey Company Plc, Vicarage Lane, Ilford, Essex

(54) **Waveform encoding method**

(57) An analogue waveform, such as a speech waveform, is converted into a digital data stream by known methods, such as Pulse Code Modulation or Delta Modulation. To achieve a reduction in the bit rate, the digital data stream is divided into a number of successive equal time periods and stored. Time encoded symbols are also derived for the digital data stored in each time period and stored. The distributions of each symbol in successive time periods are then determined and compared. The digital data stored in respect of any time period is transmitted or substituted by digital data derived from the data stored in one or more of the preceding time periods in dependence upon the results of the comparison between the symbols derived from that time period and the one or more preceding time periods.
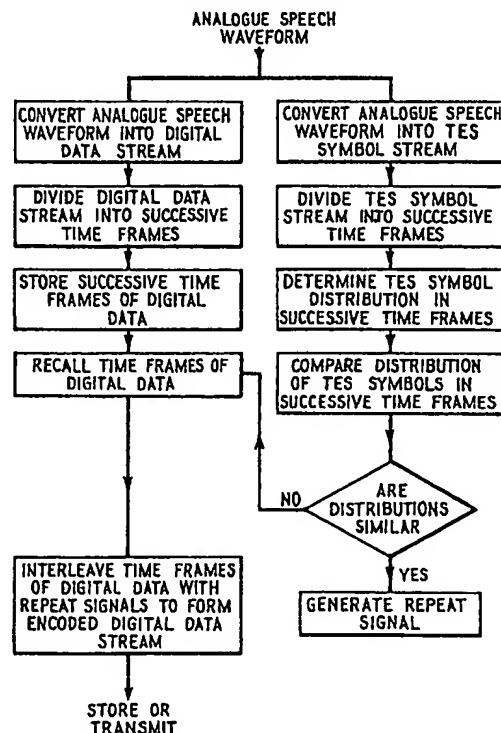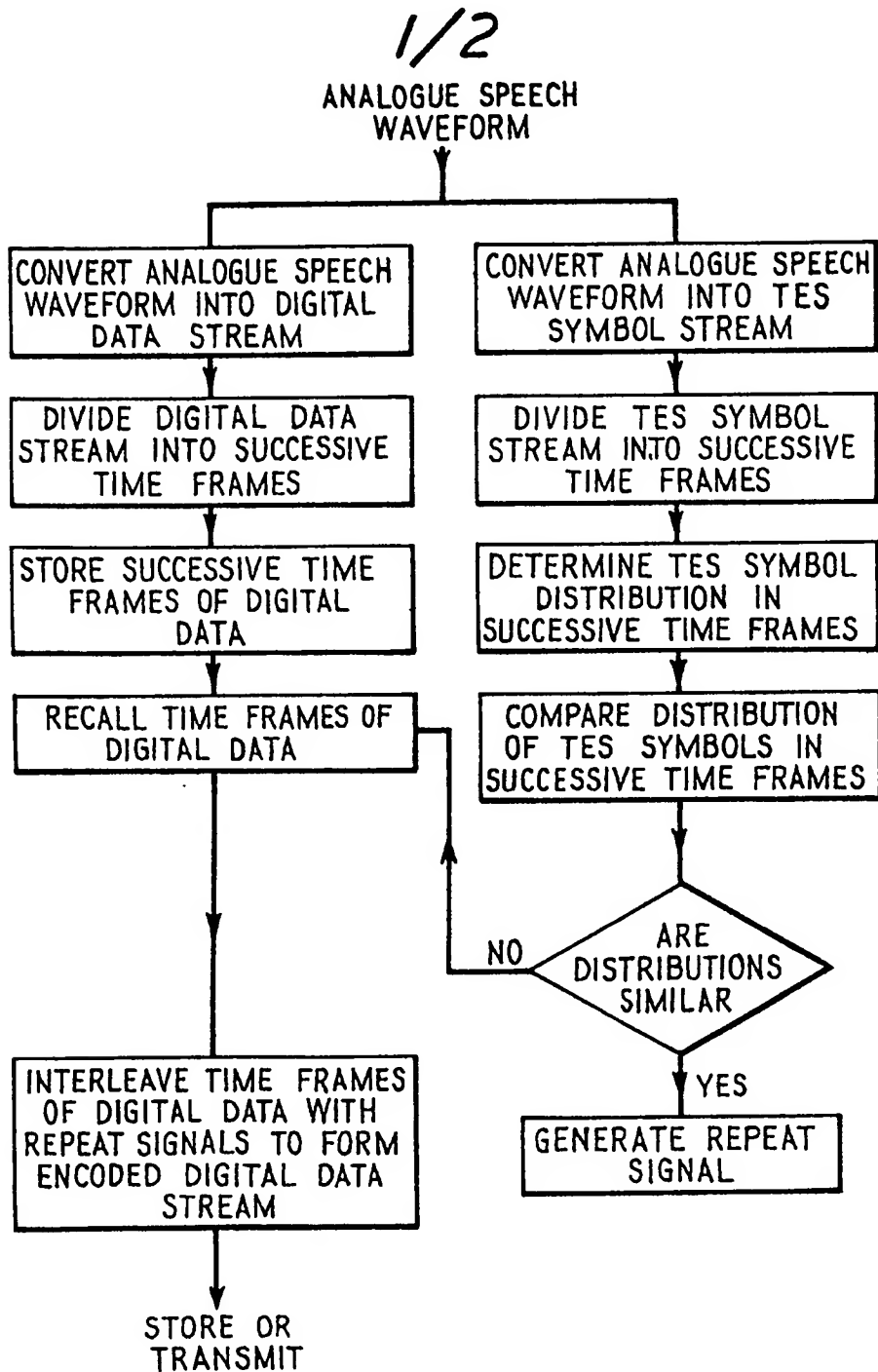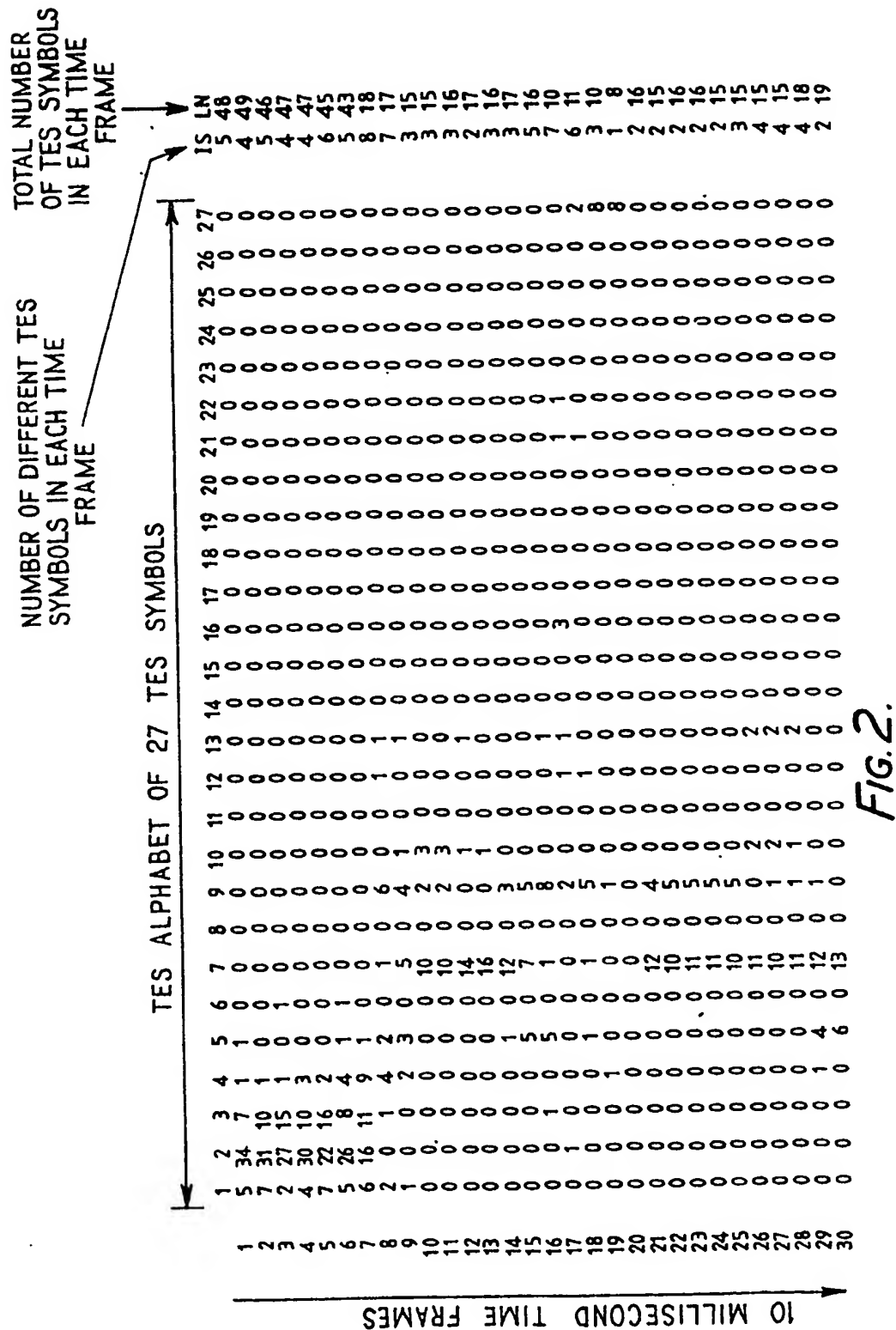

FIG. 1

GB 2 162 025 A

2162025

1/2

ANALOGUE SPEECH
WAVEFORM

CONVERT ANALOGUE SPEECH
WAVEFORM INTO DIGITAL
DATA STREAM

CONVERT ANALOGUE SPEECH
WAVEFORM INTO TES
SYMBOL STREAM

DIVIDE DIGITAL DATA
STREAM INTO SUCCESSIVE
TIME FRAMES

DIVIDE TES SYMBOL
STREAM INTO SUCCESSIVE
TIME FRAMES

STORE SUCCESSIVE TIME
FRAMES OF DIGITAL
DATA

DETERMINE TES SYMBOL
DISTRIBUTION IN
SUCCESSIVE TIME FRAMES

RECALL TIME FRAMES OF
DIGITAL DATA

COMPARE DISTRIBUTION
OF TES SYMBOLS IN
SUCCESSIVE TIME FRAMES

ARE
DISTRIBUTIONS
SIMILAR

NO

YES

INTERLEAVE TIME FRAMES
OF DIGITAL DATA WITH
REPEAT SIGNALS TO FORM
ENCODED DIGITAL DATA
STREAM

GENERATE REPEAT
SIGNAL

STORE OR
TRANSMIT

FIG. 1

TOTAL NUMBER OF TES SYMBOLS IN EACH TIME FRAME

NUMBER OF DIFFERENT TES SYMBOLS IN EACH TIME FRAME

TES ALPHABET OF 27 TES SYMBOLS

FIG. 2.

10 MILLISECOND TIME FRAMES

SPECIFICATION

Encoding method

5   The present invention relates to an encoding
method for an analogue waveform, and in particular,
but not exclusively, to an encoding method for an
analogue waveform representing speech.
        Electrical waveforms derived from human speech
10   are complex in character, having significant compo-
nents extending from below 300 Hz, to above 3kHz and
a wide dynamic range. Such waveforms may be
converted into streams of digital data by known
methods such as Pulse Code Modulation (PCM), Delta
15   Modulation or Time Encoding. In PCM, the analogue
speech waveform is sampled and a digital code is
assigned to each sample to indicate the instantaneous
amplitude of the analogue waveform at the time the
sample was taken. However, to obtain acceptable
20   quality the sampling rate must be at least double the
bandwidth of the waveform. Furthermore, the digital
code indicating amplitude normally comprises at least
an 8 bit code. Hence, assuming a bandwidth of 3kHz
for the speech waveform, it can be seen that the digital
25   data stream will contain 48 k bits/second. In most
commercial applications 64 k bits/second are gener-
ated as the bandwidth is taken as 4 kHz.
        In Delta Modulation the analogue speech waveform
is sampled, as with PCM. A single bit descriptor code is
30   then assigned to each sample in order to describe the
amplitude of the sample with respect to the preceding
sample. However, as a single bit descriptor code is
used it is necessary to use a higher sample rate than
PCM and, for commercial applications, a sample rate
35   of at least 32 k bits/second is necessary. Hence, the
digital data stream generated will contain 32 k
bits/second.
        In Time Encoding, the locations of the real zeros in
the analogue waveform are determined by quantising
40   in the time domain. The shape of the waveform
between successive zeros is then determined by
studying the number of events, e.g. maxima or
minima, in the waveform between successive real
zeros. A series of coded symbols is generated by
45   grouping the successive zeros with their associated
events. These symbols are known as TES symbols,
and the analogue speech waveform can be recon-
structed from them.
        Since the analogue speech waveform is of restricted
50   bandwidth only a limited number of coded symbols
are necessary. For example, in a speech waveform
having a bandwidth of 300 Hz to 3.3 kHz with a
sampling rate of 20k samples/second, only a limited
variation in half cycle durations can occur. At the
55   highest frequency, 3.3 kHz, the half cycle duration is
approximately 3 quanta, at the lowest frequency, 300
Hz, the half cycle duration is approximately 34 quanta.
By applying mapping logic it has been found that an
alphabet of about 27 TES symbols can be used to
60   define the analogue speech waveform. As there are
fewer than 32 symbols, a 5 bit constant length (linear)
binary word may be allocated to represent each TES

symbol. Hence, the TES symbol stream is represented
by a digital data stream of 5 bit constant length (linear)
data words. In practice, however, additional data may
be included, such as amplitude information so that
70   each symbol would be represented by a (5 +n) bit
constant length (linear) data word, where n is normal-
ly a 1 to 3 bit code word. The principles of Time
Encoded Speech (TES) are described in detail in UK
Patent No. 2020517. By adopting Time Encoding it is
75   possible to represent an analogue speech waveform
by a digital data stream having a bit rate of approx-
imately 12k bits/second, whilst maintaining accept-
able quality.
        It is often desirable to store digitally encoded speech
80   but it can be seen that, with existing methods of
encoding, large memories are required to store
relatively short periods of speech because of the
number of bits of digital information to be stored per
second of the analogue speech waveform. In order to
85   reduce memory requirements, a reduction in the bit
rate of the digital data stream is both desirable and
necessary.
        It is an object of the present invention to provide a
method of encoding data whereby the bit rate of the
90   digital data stream representing the data is reduced
substantially from that obtained with existing
methods. The method of the present invention is,
therefore, particularly applicable when it is required to
store speech in digital form. Furthermore, in transmis-
95   sion by line or radio the lower bit rate means that a
narrower bandwidth is required for transmission. If a
narrower bandwidth is not adopted the time required
to transmit a given quantity of data is reduced, which
may be particularly advantageous when the data is to
100 be transmitted by telephone line link.
        According to the present invention there is provided
an encoding method for an analogue waveform, the
method comprising deriving a digital data stream
from the analogue waveform, dividing the digital data
105 stream into a number of successive time frames of
equal time period, storing the digital data in respect of
successive time frames, deriving a stream of time
encoded symbols from the analogue waveform,
dividing the stream of time encoded symbols into
110 successive time frames corresponding to the succes-
sive time frames of the digital data stream, storing the
time encoded symbols for successive time frames,
determining and comparing the distribution of the
time encoded symbols for successive time frames,
115 and reconstructing a digital data stream from the
digital data stored and derived digital data which is
dependent upon the results of the comparison of the
time encoded symbols for successive time frames.
        Preferably the time frames are of 10 to 20 mil-
120 lisecond time period.
        The digital data derived from that stored in respect
of one or more time frames may comprise digital data
stored in the immediately preceding time frame.
        The reconstructed digital data stream may be
125 stored.
        The reconstructed digital data stream may be
transmitted.

The drawings originally filed were informal and the print here reproduced is taken from a later
filed formal copy.

The digital data stream may be derived from the analogue waveform by pulse code modulation.

The digital data stream may be derived from the analogue waveform by delta modulation.

5   The digital data stream may be derived from the analogue waveform by time encoding.

The digital data stream may be derived from the analogue waveform by any other method of digital encoding,

10   The present invention will now be described, by way of example, with reference to the accompanying drawings in which:—

Figure 1 shows a flow chart illustrating an encoding method in accordance with the present invention, and

15   Figure 2 shows a table illustrating the distribution of time encoded symbols representing a short period of speech.

Referring to the drawings, an analogue waveform, for example an analogue speech waveform, is digi-

20   tized into a digital data stream by any known method such as for example Pulse Code Modulation, Delta Modulation, or Time Encoding. The digital data stream is then divided into a number of successive time frames of equal time period and stored. In this

25   example a 10 millisecond time period has been chosen but time periods of longer or shorter duration may also be adopted. Any store suitable for storing quantities of digital information may be used to store the time frames of digital data. The division of the

30   digital data stream into the successive time frames may be achieved by gating at the required 10 millisecond time intervals.

The analogue speech waveform is also time en-coded into a stream of TES symbols. Apparatus

35   suitable for this purpose is described in UK Patent 2020517. The stream of TES symbols is also divided into a number of successive time frames of equal time period and stored such that the time frames stored in respect of the TES symbol stream correspond both in

40   time and duration to the time frames stored in respect of the digital data stream.

The distributions of the TES symbols stored in respect of successive time frames are now determined and compared. As previously mentioned the TES

45   alphabet may consist of 27 TES symbols and hence, each stored TES symbol may be represented by a 5 bit binary word. The identity of each TES symbol stored in respect of successive time frames can, therefore, be determined easily by reading the stored 5 bit binary

50   words. The frequency with which any TES symbol occurs may then be determined by incrementing a counter each time a particular 5 bit binary word is recognised. In this way a table can be formulated which shows, for successive time frames, the distribu-

55   tion of the stored TES symbols. The information contained in the table can be generated and stored in any apparatus suitable for this purpose, such as a computer.

Figure 2 illustrates the information which could be

60   contained in such a table. Figure 2 shows clearly the distribution of the TES symbols in any time frame. In time frame 1 for example, which represents the TES symbols generated by time encoding 10 milliseconds of speech, it can be seen that only TES symbols 1 to 5

65   were derived and that TES symbol 2 occurred most

frequently.

The distribution of the TES symbols in successive time frames is now compared. It can be seen from Figure 2 that there is a little change in the frequency

70   with which the TES symbols occur in time frames 1 to 7 and hence there is a little change in the distribution of the TES symbols in these time frames. This restricted change in distribution indicates that, in the speech waveform from which the TES symbols were

75   derived, there was little change in the character of the speech which occurred in time frames 1 to 7. However, it will be seen that the TES symbol distribution in time frames 8 and 9 differ from the preceding time frames and from each other which indicates a transition from

80   one speech sound to another. Time frame 11 is identical to that of time frame 10 which indicates that the character of the speech was essentially constant for this 20 millisecond period. Although the TES symbols stored in respect of time frames 10 and 11 are

85   identical, the digital data stored in respect of the same time frames of the digital data stream produced for example by Pulse Code Modulation may differ greatly in view of the sampling rate and the binary codes allocated for each sample.

90   It has been determined by analysing segmented TES symbol streams derived from speech that the TES symbol distribution may remain substantially con-stant through several 10 millisecond time periods indicating the occurence of considerable repetition

95   redundancy and the encoding method of the present invention proposes to reconstruct the digital data stream in dependence upon the results of the com-parison between the TES symbols stored in respect of successive time frames of the TES symbol stream to

100   eliminate a proportion of this repetition redundancy.

The digital data stream is reconstructed by recalling the digital data stored in respect of the successive time frames. However, the digital data stored in respect of any particular successive time frame is not recalled

105   until the distribution of the TES symbols stored in respect of that time frame has been compared with the distribution of the TES symbols stored in respect of one or more preceding time frames. The results of this comparison then determine whether the digital data in

110   the particular time frame is recalled to form part of the reconstructed digital data stream or whether the digital data in that time frame is substituted by other digital data, for example a repeat signal to indicate that the repetition of a previous time frame, with a

115   similar TES symbol distribution may be substituted. This repeated digital data may consist of the digital data stored in respect of a preceding time frame if the TES symbol distribution between the two time frames is substantially identical or it may consist of digital

120   data which is derived from the digital data stored in respect of several preceding time frames if the difference in the TES symbol distribution in these preceding time frames is within pre-determined limits.

125   This procedure may be seen more clearly with reference to Figure 2.

Referring firstly to time frames 10 and 11, if a comparison is made between the TES symbol dis-tribution in these frames it will be recognised that the

130   distributions for the two time frames are identical. As

a result of this comparison the digital data stored in respect of time frame 11 would not be recalled and a repeat signal would be generated indicating that the digital data stored in respect of time frame 10 is to be
5 repeated to replace the data stored in respect of time frame 11.

This repeat signal would replace the data stored in respect of time frame 11 and hence, the bit rate of the encoded digital data stream would be reduced in
10 comparison to the bit rate of the digital data stream derived from digitizing the analogue speech waveform by known methods, such as PCM.

Referring now to time frames 1 to 7 shown in figure 2, if a comparison is made between the TES symbol
15 distribution it can be seen there is little change between time frames 1 to 7. However, as there are several time frames having similar TES symbol distribution it may not be possible to repeat any one of these time frames seven times without affecting the
20 character of the speech reconstructed from the encoded data. Hence, the reconstructed or encoded data stream could consist of the repetition of the digital data stored in respect of a selected smaller number of these time frames with a repeat signal
25 generated to indicate when the repetition of a selected time frame is to occur. In this manner the repeated time frames are substituted in the encoded data stream by the repeat signals thereby effecting a reduction in the bit rate of the data stream whilst
30 maintaining the character of any speech reconstructed from the data.

With regard to time frames 7, 8 and 9 in Figure 2, it can be seen that these frames differ considerably from each other and therefore, a repeat strategy would not
35 be adopted for these frames since the comparison of the TES symbol distribution in these frames would not show sufficient similarity.

With reference to time frames 21 to 30 in Figure 2 it can be seen that the TES symbol distribution in time
40 frames 21 to 25 is almost identical, there being minor variations in the frequency of TES symbols 7 and 9. As a result, the digital data stored in respect of time frames 21 to 25 would not be recalled and could be substituted in the reconstructed digital data stream by
45 repeat signals indicating when a selected time frame is to be repeated, as previously described in relation to time frames 1 to 7. A similar procedure may be applied to segments 26 to 28 and segments 29 and 30 as the variations in TES symbol distribution in these time
50 frames are also slight. The digital data which is substituted into the reconstructed digital data stream may be derived according to predetermined guidelines which enable the maximum possible reduction in the bit rate whilst maintaining acceptable quality in
55 the reconstructed speech.

Therefore, by adopting the method of the present invention the analogue speech waveform is encoded into a dtream of digital data which may comprise sections of digital data derived directly by known
60 methods such as PCM interleaved with frames of digital data derived in dependence upon the results of the comparison made on the TES symbol distribution stored in respect of successive time frames.

The reconstructed digital data stream may be either
65 transmitted or stored for subsequent transmission by

known methods.

The method of the present invention is also applicable when the digital data stream comprises a TES digital data stream. In this case the presence of
70 repeat signals may preferably indicate that, for example, selected TES symbols or groups of TES symbols may be omitted throughout the time frames being compared to reduce the transmission bit rate. On reception or reconstruction the remaining TES
75 symbols or groups of TES symbols may be repeated to replace those symbols or groups of symbols selected for omission in order to reconstruct an acceptable version of the original speech waveform.

Furthermore, the present invention has been de-
80 scribed with reference to first order probability distribution but it should be understood that higher order probability distribution or alternative probability distribution may equally be used to advantage with the present invention.

85 CLAIMS
1. An encoding method for an analogue waveform, the method comprising deriving a digital data stream from the analogue waveform, dividing the digital data stream into a number of successive time
90 frames of equal time period, storing the digital data in respect of successive time frames, deriving a stream of time encoded symbols from the analogue waveform, dividing the stream of time encoded symbols into successive time frames corresponding to the
95 successive time frames of the digital data stream, storing the time encoded symbols for successive time frames, determining and comparing the distribution of the time encoded symbols for successive time frames, and reconstructing a digital data stream from
100 the digital data stored and derived digital data which is dependent upon the results of the comparison of the time encoded symbols for successive time frames.

2. A method according to claim 1 wherein the derived digital data comprises a repeat signal for
105 indicating that, when the reconstructed data stream is to be decoded, the digital data stored in respect of any time frame is to be repeated.

3. A method according to claim 1 wherein the derived digital data for a particular time frame
110 comprises the digital data stored in respect of the time frame immediately preceding the particular time frame.

4. A method according to claim 1 wherein the derived digital data comprises digital data which is
115 derived from the digital data stored in respect of one or more time frames.

5. A method according to any one of the preceding claims wherein the time frames are of 10 to 20 millisecond time period.

120 6. A method according to any one of the preceding claims wherein the reconstructed digital data stream is stored.

7. A method according to any one of claims 1 to 5 wherein the reconstructed digital data stream is
125 transmitted.

8. A method according to claim 2 wherein the digital data stream derived from the analogue waveform comprises a stream of time encoded symbols and the repeat signal is for indicating that selected
130 time encoded symbols or groups of symbols in the

digital data stream are to be omitted or repeated in the reconstructed digital data stream.

9.　A method according to any one of claims 1 to 7 wherein the digital data stream is derived from the
5　analogue waveform by pulse code modulation.

10.　A method according to any one of claims 1 to 7 wherein the digital data stream is derived from the analogue waveform by delta modulation.

11.　A method according to any one of the preced-
10　ing claims wherein the analogue waveform comprises a speech waveform.

12.　An encoding method substantially as hereinbefore described with reference to the accompanying drawings.